Technical Research Note 220

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UNAIDED READING OF CODED RECONNAISSANCE DATA

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SUPPORT SYSTEMS RESEARCH DIVISION

BESRL

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Interpreter Techniques a-22

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FOREWORD

The SURVEILLANCE SYSTEMS research program of the U. S. Army Behavioral Science Research Laboratory has as its objective the production of scientific data bearing on the extraction of information from surveillance displays, and the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. Research results are used in future systems design and in the development of enhanced techniques for all phases of the interpretation process. Research is conducted under Army RDT&E Project 2Q662704A721, "Surveillance Systems: Ground Surveillance and Target Acquisition Interpreter Techniques," FY 1970 Work Program.

The BESRL Work Unit, "Determination of Interpreter Techniques in a Surveillance Facility," conducts research to develop quick-time screening and interpretation methods that will enable an interpretation facility to process rapidly the vastly increased amounts and different kinds of imagery expected through advanced techniques for acquiring aerial imagery. The present Technical Research Note reports on a feasibility study of interpreter ability to decipher sensor and terrain information encoded on the imagery by direct inspection instead of having the data decoded by elaborate code reading machines.

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UNAIDED READING OF CODED RECONNAISSANCE DATA

BRIEF

Requirement:

To determine the feasibility of having the interpreter read sensor and flight data pertinent to a given reconnaissance mission directly from the code matrix block appearing on the imagery.

Procedure:

Code dechipering achievement was evaluated by having school-trained image interpreters read portions of 15 different code matrix blocks on which reconnaissance information was encoded. Interpreters were trained to recognize the spatial patterns of dots representing the information to the point of two error-free performances. Three five-man groups decoded each block, each group under a different level of magnification. In the experiment proper, time required for interpreters to locate the required block and decode and record the data and number of correct decodings constituted the data for analysis.

Findings:

1. The average interpreter was 98% accurate in his translation from code to clear language.

2. Reading with the unaided eye was not perceptibly aided by two-power or seven-power magnification.

3. Use of seven-power magnification reduced decoding time over two-power magnification.

4. While the best possible speed in performance was not reached with the materials used in the present experiment, practice significantly reduced decoding time. Accuracy was not affected.

Utilization of Findings:

Since few reading machines are as yet available, interpreters must be able to read the encoded data directly. Even when readers become available, interpreters working away from an automated facility will have to read the code matrix blocks directly. Procedures for interpreter practice and improvement in recognizing the spatial patterns in which reconnaissance data are encoded were suggested by the present study. Flash cards are being prepared so as to be available for self-training in the task. In addition, equipping the seven-power magnifier now issued image interpreters with a reticle designed to aid in defining the data fields would be useful.

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UNAIDED READING OF CODED RECONNAISSANCE DATA

BACKGROUND

Reconnaissance imagery is currently being acquired in which the sensor data and other pertinent information appear in coded form on the imagery. Despite the obvious intention to have the coded data read by a machine, there is a very real possibility that there will be numerous occasions where the image interpreter will be required to decipher the code. At present, the Army has very few readers in the field. Even when this shortage is rectified, the reader may fail at times or the interpreter may be working away from an automated facility. It is therefore important to determine the feasibility of having the interpreter read the coded data by direct inspection of the code matrix block.

The content of the code block as used for reconnaissance purposes is shown in Figure 1. There are 17 data fields in the three columns--columns X, Y, and Z. Each column has 32 rows and there can be as many as six dots in each row. The basic unit is one of these rows. The pattern of dots determines which of the 16 numeric values, or meanings, is displayed. The 16 possible dot patterns and the binary representation of each pattern along with its excess-three decimal equivalent is given in Figure 2.

The decimal value of each of the 16 coded patterns shown in Figure 2 can be determined by evaluating the four significant bits in each row. It is not difficult for a man to learn that the presence of a dot in D4 has the value 8, a dot in D3 has the value 4, a dot in D2 has the value 2, and a dot in D1 has the value 1. He can add these mentally, subtract three from the sum and obtain the decimal value for the row. If this decimal value is within the range 0 to 9, the pattern has immediate meaning, since the number system is already in his repertory. However, values -3, -2, -1, 10, 11, and 12 have special meanings in this context, and the interpreter must learn what these values stand for. If the interpreter can see the patterns displayed on the film, he should be able to learn to decode the data without great difficulty.

PURPOSE OF THE STUDY

The general purpose of the study was to determine the feasibility of having the image interpreter decode the matrix block by direct viewing. If the code matrix block can be read directly by the interpreter, he can function as an interim device for decoding the data. The following objectives were formulated:

1. To determine the speed with which image interpreters can decode designated portions of the code matrix block data

Line No.	COLUMN X (Index, MSB, BIT, BIT, LSB, Parity)	COLUMN Y	COLUMN Z
1	• • • • • •	o o o o o o	o o o o o o
2	o MODE	o	o
3	o o o o o o	o BLANK or	o BLANK or
4	o	o ELRAC	o
5	o RADAR	o	o ELRAC
6	o ALTITUDE	o o o o o o	o
7	o	o PITCH	o o o o o o
8	o	o	o SLR MODE
9	o o o o o o	o	o o o o o o
10	o	o	o SENSOR
11	o LONGITUDE	o o o o o o	o IDENTIFICATION
12	o	o ROLL	o
13	o	o	o o o o o o
14	o	o	o
15	o	o	o SORTIE
16	o	o o o o o o	o
17	o o o o o o	o DRIFT	o
18	o	o	o o o o o o
19	o LATITUDE	o	o
20	o	o	o
21	o	o o o o o o	o SQUADRON
22	o	o HEADING	o
23	o	o	o and
24	o o o o o o	o	o DET. NO.
25	o	o	o o o o o o
26	o TIME	o o o o o o	o
27	o GMT	o BAROMETRIC	o YEAR
28	o	o ALTITUDE	o
29	o	o	o MONTH
30	o	o	o DAY
31	o	o	o
32	o o o o o o	o o o o o o	o o o o o o

MSD - Most Significant Digit
LSD - Least Significant Digit

Figure 1. Sample reconnaissance code matrix block

The data matrix is coded in excess-three binary coded decimal. This system uses decimal numbering but is recorded in a coded binary form as listed below. The data matrix is read as a normal binary system, that is right to left, making a summation of the significant bits, then subtracting three to obtain the decimal values tabulated below:

		SIGNIFICANT BIT VALUE				ODD	
DECIMAL VALUE	INDEX BIT	D4 8	D3 4	D2 2	D1 1	CHARACTER PARITY BIT	NUMERIC VALUE OR MEANING
-3	o					o	Not Used
-2	o				o		Minus Sign (-)
-1	o			o			Error
0	o			o	o	o	Zero
1	o		o				One
2	o		o		o	o	Two
3	o		o	o		o	Three
4	o		o	o	o		Four
5	o	o					Five
6	o	o			o	o	Six
7	o	o		o		o	Seven
8	o	o		o	o		Eight
9	o	o	o			o	Nine
10	o	o	o		o		Plus Sign (+)
11	o	o	o	o			Special
12	o	o	o	o	o	o	Divider

NOTES:

1. The index mark is always present.
2. The parity bit is present to cause the total count of dots across one column to be an even number. This provides the "odd parity check" to insure that the bit recording is correct.
3. The divider is used as a visual indicator to separate major groups of characters within the code matrix block.
4. Significant bits progress from D4 (most significant) through D1 (least significant).
5. "Error" indicates the information generated for recording is outside the range of the particular sensing device in use.
6. "Special" indicates that the information normally presented in this location will be found in some external device.
7. A plus or minus code may occur in the code matrix block. This is an acceptable coded digit. The plus and minus code convention is as follows:

	Plus (+) Code	Minus (-) Code
Latitude	North	South
Longitude	East	West
Drift	A/C Nose Left of Ground Track.	A/C Nose Right of Ground Track.
Roll	Right Wing Down	Right Wing Up
Pitch	Nose Up	Nose Down

Figure 2. Data matrix coding

2. To determine the accuracy of their performance

3. To determine the usefulness of magnifying the code matrix block as a means of enhancing the speed and accuracy with which interpreters can decode the matrix content.

METHOD

Experimental Design

The following design was established: Three different levels of magnification were chosen--single power (the unaided eye), two-power (the stereoscope), and seven-power (tube magnifier). These levels were selected because instrumentation is available with the present Photo Interpreter Kit routinely issued to interpreters.

A 16-exposure roll of five-inch imagery containing code matrix data for each frame was used. One exposure was excluded arbitrarily. The 15 remaining frames were grouped into three sets of five exposures each. The five exposures in any set were not necessarily contiguous.

In order to control for practice and boredom effects, each of three interpreter groups used a different magnification in deciphering each set of five items. Figure 3 is a schematic representation of this simple design. Every group of interpreters worked through the items in the order 1 through 15. When the first five items to be done under one level of magnification were completed, the interpreter moved on to the next set of five and did those under the prescribed level of magnification, then moved on to the last set of items. In this way, each set of five items was deciphered at each of the three levels of magnification. Consequently, a given level could not appear to be advantageous or disadvantageous merely because practice or boredom enhanced or attenuated interpreter performance.

		Interpreter Group		
		G_1	G_2	G_3
Item Set	S_1 Items (1- 5)	M_{1X}	M_{2X}	M_{7X}
	S_2 Items (6-10)	M_{2X}	M_{7X}	M_{1X}
	S_3 Items (11-15)	M_{7X}	M_{1X}	M_{2X}

Figure 3. Experimental design

Sample

Sixteen recent graduates of the Image Interpretation Course of the U. S. Army Intelligence School at Fort Holabird, Maryland, plus one experienced image interpreter assigned to the Behavioral Science Research Laboratory took part in the experiment. All had met the General Technical Aptitude Area score school requirement of 100 or above. The men were trained and tested during one half-day period. Three different sessions were conducted, each on a separate day. The sessions involved groups of six, five, and six men, respectively. Of the 17 tested, 15 were included in the analysis.

Preparation of Materials

The manner in which a man can be trained to determine the decimal equivalent of a binary display containing four significant bits has already been described briefly. This training approach establishes a work pattern that tends to produce slow decoding rates. In an effort to speed up the decoding process, it was decided to try training the interpreter to recognize the pattern as a whole and not require him to decipher it. It was reasoned that since Morse Code, an auditory pattern, is learned by most trainees to some level of competence, the simpler 16-element visual code employed in the code matrix block could be taught in analogous fashion. If one of the dot patterns was displayed followed by the number or symbol for which it stands (the paired-associate learning method), the interpreter could be expected to associate the appearance of the dot pattern with its meaning after a few repetitions.

A scale model of the fixed dot configuration of the code matrix block was prepared. In Figure 4, the rows are numbered and the columns are labeled for descriptive purposes, but the row and column designators did not appear on the master prepared for development of the training materials. The total matrix, if all positions were filled, would contain 576 dots. The fixed dot configuration has a total of 196 dots. These fixed dots are needed for location purposes but do not contain specific sensor data or acquisition information.

Row 13 of column X was chosen as the position in which the various dot patterns would be displayed in the materials used for training. An arrowhead was placed on the master sketch to call attention to this location. In preparing the 35 mm slides, one of the 16 dot patterns was laid out in Row 13, using removable dots of the same size as those which made up the fixed skeleton of the block. This pattern was photographed, the pattern changed, and the process repeated until all 16 patterns had been photographed.

A second set of 16 slides was made on which the meaning of each code appeared, one meaning to a slide. This meaning might be one of the numerals, zero to nine, or one of the six non-numeric meanings in the code block. The total set of slides--patterns and meanings--consisted of 32 slides. Since the projector magazines on hand would accept but 30 slides, one pair of slides was discarded. The "Not Used" code was not relevant for the test materials to be used in the study, and the two slides associated with this code were removed from the set.

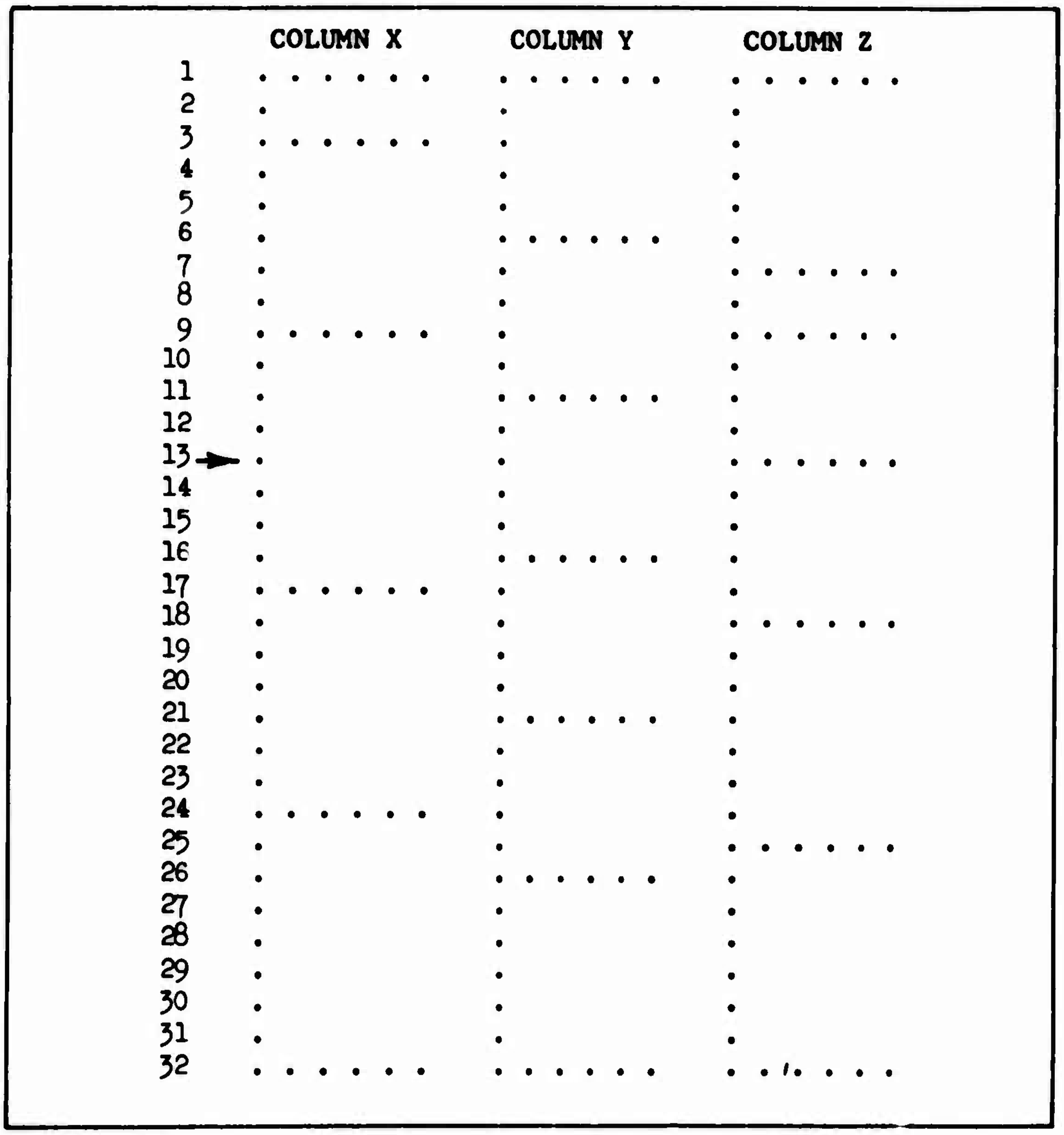


Figure 4. Skeletal framework of code matrix block

A set of general instructions was prepared for distribution to the interpreters prior to training with the slides. Instructions and practice materials appear in the Appendix. To fix more firmly the perceptual pattern of each code, a set of practice exercises in paper and pencil format was prepared, including a set of flash cards and printed instructions for their use. These flash cards carried a sketch of a portion of one column of the block with one row filled with one of the codes. On the back of the card was the deciphered equivalent of the dot pattern. The instructions described the use of the cards and cautioned the user to shuffle the deck after each run to avoid serial effects in learning. Record sheets were used in training the men to recognize the dot patterns and in appraising their achievement with real code matrix blocks after training had been completed.

Administration of the Experiment

The five--or six--interpreters participating in a session were placed at tables where all had a clear view of the screen on which the slides were to be projected. Each station was equipped with a light table for backlighting the photographic transparencies. The instruction sheet containing the display of the 15 dot patterns to be learned was distributed. After these had been read and the dot patterns and their meanings studied, the set of practice examples and the instructions were distributed. Each man read the instructions and then proceeded to fill out the dot patterns for each of the symbols and numbers indicated. The men were permitted to use the instructional materials as an aid in completing this task. When this portion had been completed and discussed, each man was given the instruction sheet and a set of flash cards. While the men practiced with the flash cards, the projection equipment and the timer were readied for projecting the first trial for training the men to recognize the dot patterns without reference to any guide sheet.

The projector changed slides automatically and could be actuated by the variable timer. Initially, slides were projected one every ten seconds. Later, the time was shortened to one every five seconds. The time allowed was ample to permit the men to write their response to the dot pattern and to check the accuracy of that response when the definition slide was presented.

The Dot Pattern Recognition Sheet was given to each man. He entered his name and the sheet number in the appropriate blanks and then wrote the trial number (Number 1 for the first trial) in the space for the second column heading. He was then given the following verbal instructions:

> AS EACH PATTERN OF DOTS IS DISPLAYED, WRITE THE MEANING OF THE PATTERN IN THE APPROPRIATE ROW OF THE TRIAL YOU ARE WORKING ON. WHEN THE ANSWER IS PROJECTED, CHECK YOUR RESPONSE WITH THE ACTUAL MEANING. IF THEY AGREE, DO NOTHING. IF THEY DISAGREE, MARK AN X THROUGH YOUR ANSWER. AFTER YOU HAVE CHECKED THE LAST ANSWER IN THE COLUMN, ADD UP THE NUMBER OF CORRECT RESPONSES MADE BY YOU IN THAT COLUMN. WRITE THIS NUMBER IN THE SPACE PROVIDED AT THE BOTTOM OF THE COLUMN.

Any questions were resolved and the trial began.

Presentation order for each trial was determined from a prearranged list of random orders. The reason for changing slide order from trial to trial was to control any serial effects in learning. If the order was held constant, the interpreter might recall that a particular symbol was first, last, or that it followed some other symbol, and thus he might appear to have learned to recognize the dot pattern when, in fact, he had merely learned the order of appearance. By changing order, each pattern had to be learned in terms of its own spatial configuration, since the order of its appearance in the list was random from one trial to the next.

Successive trials were run until every trainee reached the required two consecutive error-free trials. The largest number of trials required for a trainee to reach this criterion was 23. There were great individual differences. The average interpreter required about nine trials. Several men reached the criterion in six trials. Once the criterion had been reached by all men in the group, the test proper began.

Each man was given a roll of film containing 16 exposures of five-inch photographic transparencies and an answer sheet. All film copies were of the same content. Each of the 15 rows on the answer sheet referred to a specific exposure. Every man worked through the list of tasks in exactly the same order. However, the magnification used varied with groups of interpreters. The manner in which the interpreter did his tasks can best be described by example: The first row requires the man to roll through the film until he locates exposure number 104. Each exposure in the roll is identified by an arabic numeral written in the center of the upper margin of the film. Prior to starting, the man recorded his starting time to the nearest minute. He then located exposure 104 and read the code block and recorded the radar altitude, the longitude, the latitude, and the Greenwich mean time. He recorded the time of completion of the first row and then went on to the second row of the answer sheet and repeated the procedure until he had completed all 15 rows. For each set of five items, he used the magnification level written in the extreme right-hand column of the answer sheet.

The time required for the experiment included about one hour for training the average interpreter to the criterion adopted for the experiment. Reading the required data blocks as directed in the answer sheet took about another hour. The entire experiment including rest periods was accomplished without difficulty in the half day allotted.

Variables

The variables were mentioned in the discussion of the experimental design, but they are repeated here in greater detail. There were three independent dimensions. The first was the level of magnification used (no magnification, two-power magnification, and seven-power magnification).

The second variable was the order in which the three levels of magnification were used by the interpreter as he worked through the 15 tasks. The first five items were done with one magnification, the second five with another magnification, and the last five with still another magnification. The three orders employed were 1X-2X-7X, 2X-7X-1X, and 7X-1X-2X. Each interpreter group used one of the three orders. A third dimension was item set. The 15 code blocks were grouped into three sets of five blocks each. The number of dot patterns and the methods used to locate the proper film exposures were held constant among the three sets.

Deciphering performance was assessed by two dependent measures: length of time required to complete the assigned tasks and number of dot patterns correctly deciphered. From these basic measures two indices were derived:

Response Accuracy. Ratio of the number of correct responses to the total number of responses made. Since each interpreter was required to respond to all items, the total number of responses made was a constant. Because of the foregoing constraint, the response accuracy index was equivalent to a response completeness index.

Deciphering Rate. Ratio of the total number of responses to the amount of time, in minutes, required to make the required responses, regardless of the correctness of the responses. If the rate at which correct responses were produced is desired, it can be obtained by multiplying the deciphering rate by the response accuracy.

Statistical Computations

The effects of magnification, item set, and interpreter group upon performance were determined by analysis of variance techniques for the Latin square design. Separate analyses were conducted for response time and for the number of correct responses made.

One of the main objectives of the study was to establish average performance figures for interpreters reading the code matrix block data by inspection. Consequently, several analyses were concerned with descriptive statistics.

RESULTS

Effect of Magnification

Physically, the data block recorded on aerial reconnaissance film is very small, about three-eights of an inch wide and one-half inch long. In less than one fifth of a square inch are packed the reconnaissance data in excess-three binary code. The initial assumption was that speed and accuracy of performance for direct visual reading of the block would be improved by furnishing some amount of magnification. The validity of this assumption is examined in the following paragraphs.

Table 1 shows the number of minutes required by the average interpreter to locate five specified exposures in the film roll and then read the required dot patterns from the data blocks on these exposures. There was a total of 87 patterns in each set of five exposures and a total of 261 patterns for the entire task. For the total task, the average composite interpreter required about 41 minutes using 1-power magnification, 46 minutes with 2-power magnification, and 38 minutes with 7-power magnification.

Table 2 summarizes the analysis of variance results for these time scores. Magnification is seen to have produced a statistically significant difference in performance at the .05 level of confidence. Using the Newman-Keuls method to test the significance among the three magnification levels revealed that only the difference between 2-power and 7-power magnification was significant. This seemingly inconsistent finding--no magnification was neither better than two-power magnification nor poorer than seven-power magnification with respect to amount of time required, but seven-power was significantly better than two-power--may be an artifact. The two-power magnifier in the Photo Interpretation Kit is a folding stereoscope, whereas the seven-power magnifier is similar to a jeweler's glass and can be placed directly over the spot to be magnified. The stereoscope stands on folding wire supports and must be held to have stability. This awkward characteristic may well have been responsible for the longer performance time observed in the experiment. In fact, several interpreters asked the experimenter if they might use no magnification rather than use the two-power magnification. (Obviously, these requests were denied in order to conform to the design requirements.)

Table 1

MEAN PERFORMANCE TIME IN MINUTES

	Magnification Level			
Task	1-Power	2-Power	7-Power	Average
Set 1	18.8	21.6	15.0	18.5
Set 2	11.2	15.0	14.2	13.5
Set 3	11.2	9.6	9.0	9.9
TOTAL	41.2	46.2	38.2	41.9

Table 2

ANALYSIS OF VARIANCE SUMMARY:
PERFORMANCE TIMES FOR INITIAL, MIDDLE, AND FINAL THIRDS OF TOTAL TASK

Source of Variation	Sum of Squares	df	Mean Square	F	$F_{.95}$	$F_{.99}$
Between						
Groups	106.7111	2	53.3556	1.3343	3.88	6.93
Subjects within Groups = (e_1)	479.8667	12	39.9889	------		
Within						
Sets	551.5111	2	275.7556	38.0936**	3.40	5.61
Magnification	54.4444	2	27.2222	3.7605*	3.40	5.61
Latin Square Resid.	1.6444	2	.8222	.1136	3.40	5.61
Sets x Subjects within Groups = (e_2)	173.7333	24	7.2389	-------		
TOTAL	1367.9111	44	--------	-------		

*Significant main effect, $P < .05$.
**Significant main effect, $P < .01$.

Table 3 shows the number of correct responses made by the average interpreter on the several portions of the experimental task. The average interpreter using 1-power magnification made 256 correct responses out of a possible 261; the interpreter using 2-power and 7-power magnification made 257 and 256 correct responses, respectively. Magnification is thus seen to make little difference in the total number of correct responses made by the average interpreter.

Table 4 shows the analysis of variance summary for these data. Statistically, level of magnification produced no significant effect upon number of correct responses.

In general, it appears that magnification has no beneficial effect upon the number of correct responses the interpreter makes in reading the code matrix block data. He does perform more rapidly when he uses seven-power magnification than when he uses two-power magnification, but the advantage disappears when compared with performance without magnification. Additional work is required before a definitive assessment of the value of magnification can be made.

Table 3

MEAN NUMBER OF CORRECT RESPONSES

Task	Magnification Level 1-Power	2-Power	7-Power	Average
Set 1	85.0	86.0	84.4	85.1
Set 2	85.4	85.6	86.4	85.8
Set 3	85.2	85.2	85.2	85.2
TOTAL	255.6	256.8	256.0	256.1

Table 4

ANALYSIS OF VARIANCE SUMMARY:
CORRECT RESPONSES FOR INITIAL, MIDDLE, AND FINAL THIRDS OF TOTAL TASK

Source of Variation	Sum of Squares	df	Mean Square	F	$F_{.95}$	$F_{.99}$
<u>Between</u>						
Groups	5.9111	2	2.9556	.4926	3.88	6.93
Subjects within Groups = (e_1)	72.0000	12	6.0000	-----		
<u>Within</u>						
Sets	4.0445	2	2.0222	.7444	3.40	5.61
Magnification	1.2445	2	.6222	.2290	3.40	5.61
Latin Square Resid.	2.1777	2	1.0889	.4008	3.40	5.61
Sets x Subjects within Groups = (e_2)	65.2000	24	2.7167	-----		
TOTAL	150.5778	44	------	-----		

Disregarding the ambiguity associated with the value of magnification upon reading speed, a case can still be made for using some level of enlargement to facilitate reading. One problem associated with direct reading of the coded data is that of finding the proper data field and keeping the place once the proper field is located. Several tube magnifiers used by interpreters are equipped with removable reticles which provide measurement capability. These graduated scales screw on to the base of the magnifiers. If a locating device were etched upon a piece of plastic and mounted in one of these reticle rings, it could be fastened directly to one of the maginifiers issued in the Photo Interpreter Kit. This device would enable the interpreter to identify the various data fields and would designate the dot patterns pertinent to each field. A homely prototype of such a device is sketched in Figure 5. A non-removable device has been made in BESRL's Information Systems Laboratory and has been attached to an eight-power tube magnifier, non-issue.

No consideration was given to the effect of magnification under protracted periods of work. The average interpreter in the experiment spent about 42 minutes in locating the appropriate 15 code blocks, decoding the relevant 261 dot patterns, and recording the data in uncoded form on his answer sheet. If the division lines (dividers) appearing in the code block are disregarded, the total number of data-bearing dot patterns in a single block is 76. The 261 patterns read in this experiment would comprise somewhat less than 3 1/2 completely filled blocks. How an interpreter might perform after a long work period or whether magnification would be important under such conditions was beyond the scope of the experiment.

Response Accuracy

The number of correct responses was independent of both the magnification employed and the amount of practice involved. Table 3 shows that the mean number of correct responses made by the 15 interpreters was 85.1 for the first set of five items, 85.8 for the second set of five, and 85.2 for the third set. Item set did not produce a statistically significant difference in performance, as shown by the summary of analysis of variance given in Table 4.

Average performance for the various segments of the total task expressed as a proportion of the maximum possible showed that performance was 98 percent accurate for set 1, 99 percent accurate for set 2, and 98 percent accurate for set 3. Accuracy for the total task was 98 percent.

The above results are plotted in Figure 6. The left-hand ordinate shows the number of correct responses per set and the number of errors that would be associated with that number of correct responses. The ordinate scale at the extreme right shows the response accuracy index associated with each number of correct responses. The graph shows the average performance of a single interpreter.

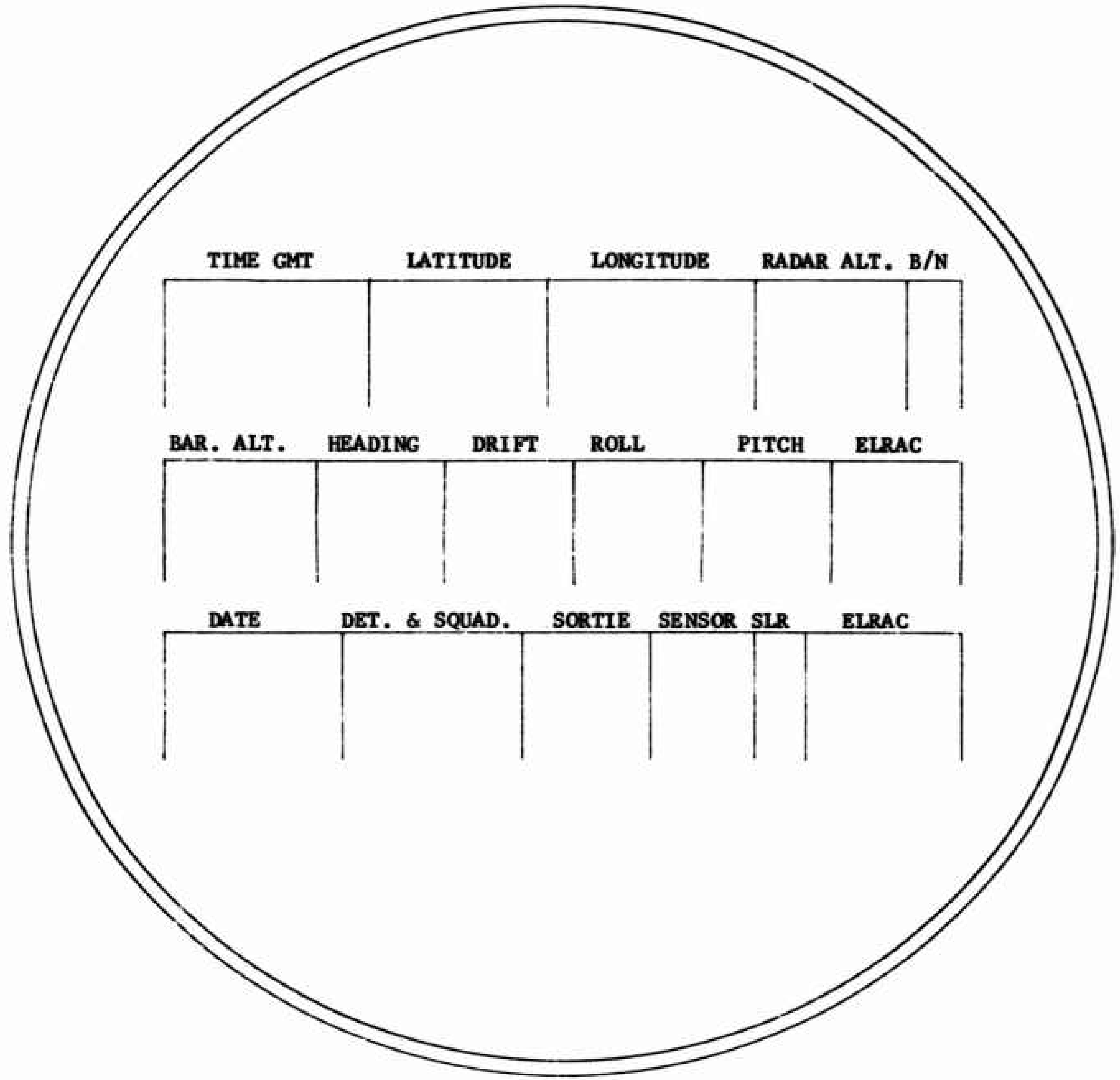


Figure 5. Code matrix block field designating reticle scale: 10:1 (approximate)

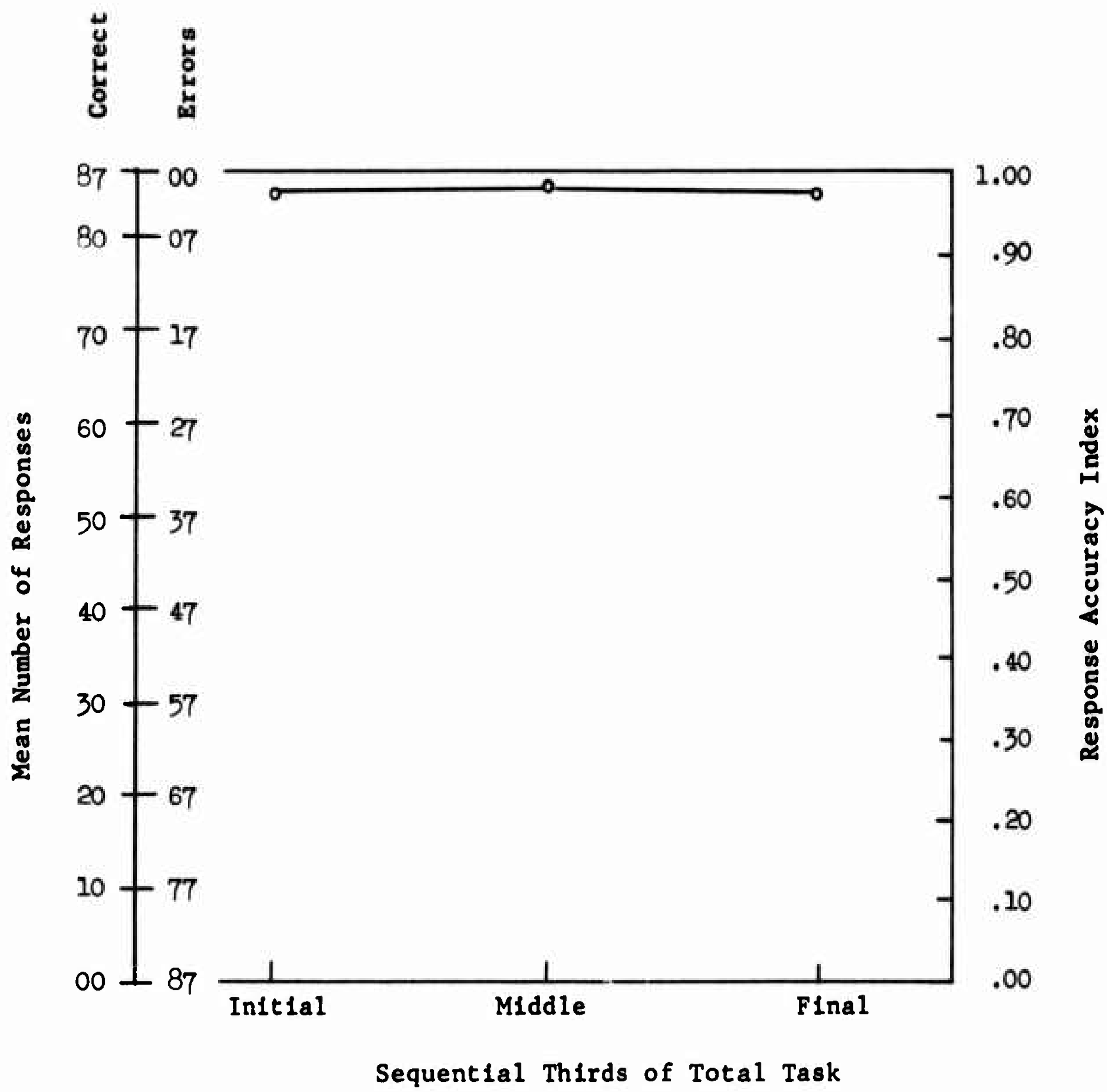


Figure 6. Mean responses for thirds of the total task

The rapidity with which the average interpreter can decode the matrix block is of considerable interest. Referring back to Table 1, we see that the mean time required by 15 interpreters to decode the 87 dot patterns in each set continued to decrease with practice. Set 1 required 18.5 minutes, set 2 required 13.5 minutes, and set 3 required 9.9 minutes. The summary of the analysis of variance in Table 2 shows that set differences were highly significant. The Newman-Keuls method indicates that all inter-set differences were highly significant. It is apparent that practice constantly improved the average interpreter's speed of response. The ultimate leveling-off point could not be estimated from the present experimental results.

The time scores were analyzed in another manner. Since the time score for each exposure was the sum of the time required to locate the exposure, to decode the dot patterns, and to record the required data, location, decoding, and recording time was confounded. Location by serial exposure number minimized the time needed for this aspect of the task. Thus, the time estimate derived from such an item gave a better estimate of the time required for deciphering and recording.

The second method of locating the exposure is typified by item two. Here the interpreter looks for that exposure which has the designated longitude and latitude. He looks at the relevant blocks on the tentatively selected exposure to see if it reads 94° 42.6' West and 32° 54.4' North. If it does not, he goes on until he locates the proper exposure. Then he reads and records the required data. Here, the location phase takes a much greater portion of time than the first method.

The third method is illustrated by item three. The Greenwich mean time is given on the answer sheet. The interpreter looks for the exposure which has that time recorded in the time field of the code block. Once he finds the proper exposure, he decodes and records the data asked for. This third method is less difficult than the second. Only one data field must be read to identify the appropriate exposure. Also, time increases from the beginning to the end of the roll. Therefore, the interpreter can immediately tell upon reading time on a tentatively selected block whether he should proceed toward the end of the mission or go back toward the start of the mission. These latter two methods are both more difficult than the first method. Therefore, more time is used in locating the proper exposure, and these two methods give poorer estimates of decoding and recording speed by themselves.

Table 5 separates the five time scores obtained in each set into three categories dependent upon the method used to locate the appropriate exposure. The number of dot patterns to be deciphered is shown for each category and the number of minutes required by the average interpreter to do the task is also given. These same data are tabulated for the other two sets and for the total task. The deciphering rate for the various categories is given in the extreme right-hand column. To show the effect of practice upon performance, the results for the category of task where exposure location was determined by Exposure Number (arabic numeral) are given. For set 1 the rate was 5.89 dot patterns per minute while for set 2 it increased to 11.25 dot patterns per minute and for set 3 to 16.30 dot patterns per minute.

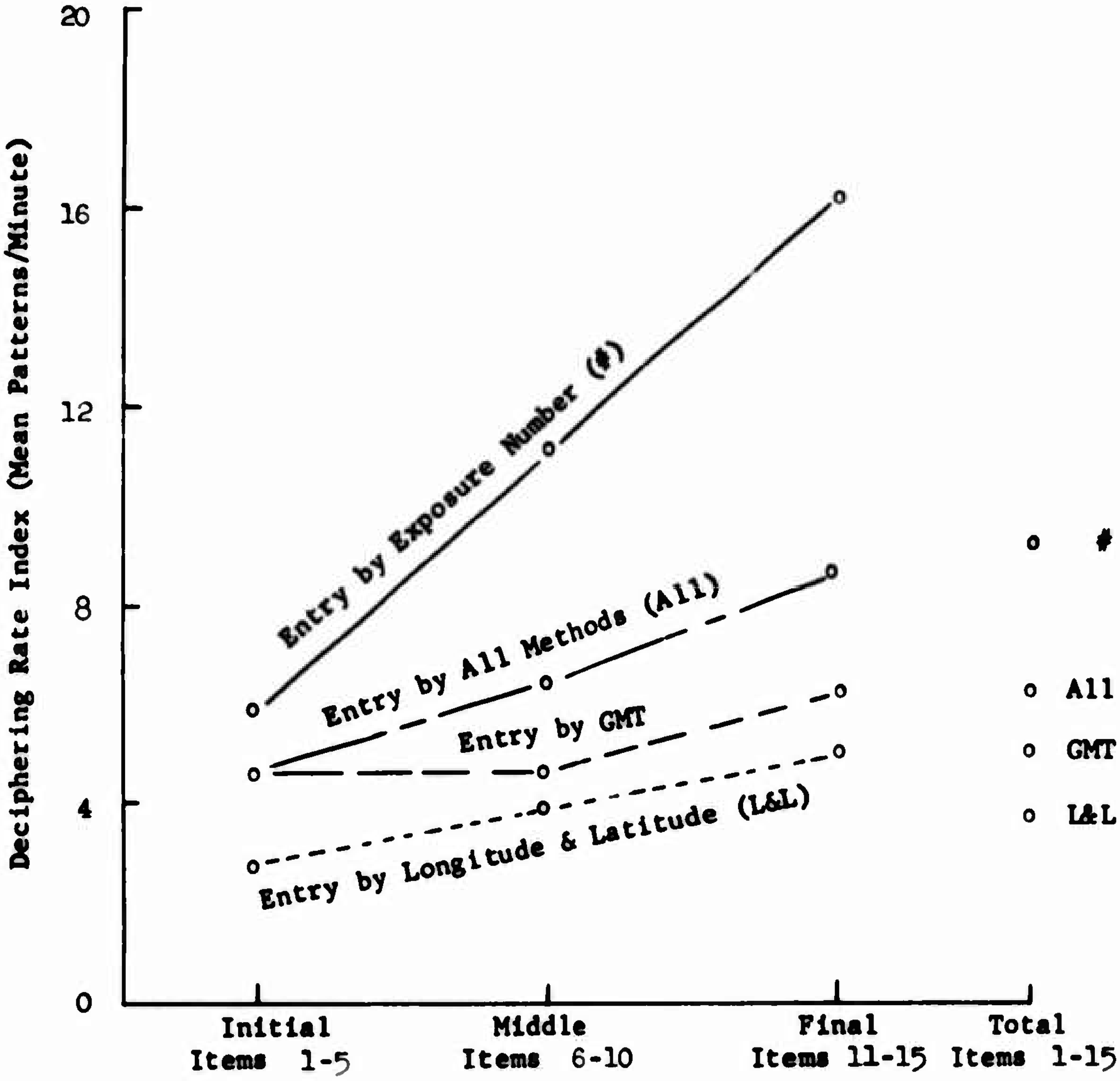
Table 5

MEAN DECIPHERING RATE

Task Segment	Exposure Location Code	Number of Dot Patterns	Mean Time (Minutes)	Deciphering Rate Dot Patterns/Minute
	#[a]	44	7.467	5.89
Set 1	L&L	12	4.267	2.81
	GMT	31	6.733	4.60
	#	44	3.911	11.25
Set 2	L&L	12	3.033	3.96
	GMT	31	6.522	4.75
	#	44	2.700	16.30
Set 3	L&L	12	2.344	5.12
	GMT	31	4.889	6.34
	#	132	14.078	9.38
TOTAL	L&L	36	9.644	3.73
	GMT	93	18.144	5.13

[a]Exposure Location Code: # = Exposure located by Arabic numeral in film margin.
L&L = Exposure located by longitude and latitude fields in the code matrix block.
GMT = Exposure located by Greenwich mean time field in the code matrix block.

These rates more nearly approximate reading speed since this method of locating the desired exposure is the easiest. Notice that rate continued to improve over time because of practice effect. Figure 7 shows these results graphically. The improvement achieved for entry by exposure number was greater than that achieved for either of the other two entry methods or for all three combined. The averages over all fifteen items are graphed as point values at the extreme right of Figure 7. The improvement can be inferred to result from improved dot pattern recognition. For the other two methods, entry time took a disproportionate amount of the observed time and consequently the improvement was far less noticeable.



7. Deciphering rate index by method for thirds and all of the total task

The ceiling rate for reading coded data could not be directly determined from this study. It can be said that practice has a beneficial effect upon response time. In establishing training procedure for teaching interpreters to decode the block, greater emphasis should be placed upon overlearning of the dot patterns coupled with extensive practice in decoding actual data blocks. How much practice? This will have to be determined empirically.

The rates reported here are for the number of dot patterns processed and disregards the fact that not all patterns were correctly decoded. The rate for producing correct responses, can be obtained by multiplying the Deciphering Rate Index reported by the Response Accuracy Index previously described. Since the Response Accuracy Index was 98 percent at a minimum, the Deciphering Rate Index for correct responses will be within two percent of the values reported.

SUMMARY OF RESULTS

The principal results were:

1. Time taken to read the code matrix block with the unaided eye was not perceptibly reduced by use of seven-power or two-power magnification.

2. Use of seven-power magnification produced a statistically significant reduction in response time over two-power magnification.

3. Practice over the limited total task resulted in statistically significant reductions in response time. The terminal threshold for performance time was not reached in the experiment.

4. The number of correct translations from coded format to clear text was independent of magnification and practice. The average interpreter was 98 percent accurate in decoding.

5. The deciphering rate index was defined as the number of correct translations per minute. Since response time included time to decode plus time required to locate the proper code block, the obtained rates were depressed below what they should be for deciphering performance. For the easiest method of locating the appropriate block, the average rate was 16.3 patterns per minute for the last pair of blocks translated using this location method. This was the fastest rate obtained.

CONCLUSIONS

With respect to the value of magnification in decoding matrix block data, as measured by accuracy and speed of response, the interpreter decoding without magnification does as well as the man decoding with either two-power or seven-power magnification. The statistically significant reduction in response time observed for seven-power magnification as compared with two-power may be an artifact. The two-power magnifier was a

stereoscope and its cumbersome characteristics may have been responsible for the increase in response time. The advantage of magnification for long work periods cannot be generalized from the results obtained here. These results were based on an average work period of about 40 minutes and cannot be assumed to hold for longer work periods.

Decoding errors were relatively few. After initial training, the average interpreter was about 98 percent correct in his translation from code to clear language. Practice produced no significant change in the number of erroneous responses made over the work period used in the study. Error rates for longer work periods must be determined empirically.

The deciphering rate expresses correct responses as a function of the time required to make responses. Since response time decreased significantly for successive thirds of the total task, improvement was constant and the terminal rate could not be estimated.

The paired-associate learning technique appears to work extremely well in training interpreters to recognize the various dot patterns used to encode reconnaissance data. A more stringent criterion might have served to speed up the process by which the interpreter can reach optimal response rates.

Although the need for magnification in the short decoding task used in the experiment was not conclusively demonstrated, the use of some low power magnification coupled with a special purpose template-type reticle is judged to be desirable. Such a reticle would define the specific data fields in the block and would assist the interpreter in keeping his place while reading and recording the desired information.

The following procedures have been suggested on the basis of the research as means of providing the image interpreter with the requisite skills and of aiding him in reading data from the code matrix block when the need arises:

A training unit should be introduced to instruct student and operational image interpreters in recognizing the 16 spatial patterns used to encode reconnaissance data. BESRL research scientists are preparing materials for use in such practice, following the method used in the present experiment. These include a set of flash cards of playing-card size for self-training in pattern recognition.

A magnifier equipped with a reticle which serves as a template to define the 17 data fields and helps the interpreter keep his place as he decodes should be provided. This may well take the form of an additional reticle for the seven-power tube magnifier currently issued. A prototype device has been prepared.

The relative merits of the pattern recognition approach should be evaluated in comparison with the method of computing the decimal value of the excess-three binary code for training image interpreters to decode the code matrix block. The latter method is easily and rapidly taught and readily retained. The pattern recognition method may be more difficult to retain even though considerable overlearning is required in initial training. Forgetting rates for the two methods as well as ultimate performance rates should be compared. Subjectively, it is judged that the pattern recognition method of training will lead to more rapid deciphering rates.

Terminal performance data should be obtained using experimental tasks sufficiently long and complex to insure that any learning plateaus are exceeded. Experiments conducted in the learning of complex tasks frequently show periods during which no improvement in performance takes place; but when additional training is given, performance is found to improve.

APPENDIX

INSTRUCTIONS TO SUBJECTS AND MATERIALS USED IN THE EXPERIMENT

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INSTRUCTIONS FOR PRACTICE IN DECIPHERING THE CODE MATRIX BLOCK BY INSPECTION

The following instructions have been prepared to assist those persons who must learn to read the code matrix block visually. There are 15 distinct spatial patterns used to code the ten numerals and five special symbols. Every row in the three columns which comprise the code matrix block is one of these 15 spatial displays. The complete block on any piece of imagery contains 96 of these spatial patterns.

Look at the large-scale drawing of the code matrix block. There are three columns of 32 rows each, with space for six dots in each row. There are 17 different fields represented in this skeletal block. These fields are separated from each other by a row of six dots known as a divider. This divider is one of the 15 spatial patterns mentioned in the previous paragraph.

On the next page, the arrangement of dots in the spatial pattern used to code each of the numerals and symbols appears. The arrangement of the dots is giver at the left of the page with the associated numerical or symbolic equivalent given at the right side of the page.

Study these spatial patterns and their associated meanings until you are certain that you can recognize them when you see them again. You will be given as much time as you need for this task.

GO AHEAD TO THE NEXT PAGE.

PRECEDING PAGE BLANK

PATTERN						MEANING	
•	•	•	•	•	•	Divider	(used to separate fields)
•				•		-	(minus sign)
•			•			Error	(used to designate error in data)
•		•				1	
•	•					5	
•	•	•	•	•	•	Divider	(used to separate patterns)
•			•	•	•	0	
•		•		•	•	2	
•		•	•		•	3	
•	•			•	•	6	
•	•		•		•	7	
•	•	•			•	9	
•	•	•	•	•	•	Divider	(used to separate patterns)
•		•	•	•		4	
•	•		•	•		8	
•	•	•		•		+	(plus sign)
•	•	•	•			Special	(used for varied purposes)
•	•	•	•	•	•	Divider	(used for separate patterns)

Figure A-1. Spatial Patterns and Associated Meanings

Notice that the number of dots in each row is always an even number. There may be two, four, or six dots in a row. If there is an odd number of dots in a row, that code is in error.

WAIT HERE FOR FURTHER INSTRUCTIONS.

INSTRUCTIONS FOR PRACTICE IN CODING NUMBERS AND SYMBOLS

To fix more firmly the relation between dot patterns and the numbers or symbols for which they stand, the following task has been developed. Here you are given a number or symbol and you are asked to write the dot pattern used to code it. LOOK AT THE FOLLOWING SAMPLE.

Symbol or Number to be Coded	Dot Pattern
6	. _ _ _ _ _

Since the left most dot is always present in every dot pattern, it will always be given in these practice problems. The position to be occupied by any of the other five dots required to make the dot pattern is marked by an underscore. You are to place dots in those positions required to code the symbol or number shown. The person marking this practice problem showed his response in the following way:

Symbol or Number to be Coded	Dot Pattern
6	. ° _ _ ° °

Each of the practice problems on the next page is to be answered in this way, Go through the two columns coding each symbol or number. When you have finished, we will check the accuracy of your responses.

Are there any questions concerning this task? If there are no further questions, go right ahead.

Symbol or Number to be Coded	Dot Pattern	Symbol or Number to be Coded	Dot Pattern
+	. _ _ _ _ _	0	. _ _ _ _ _
Divider	. _ _ _ _ _	9	. _ _ _ _ _
Error	. _ _ _ _ _	1	. _ _ _ _ _
8	. _ _ _ _ _	4	. _ _ _ _ _
3	. _ _ _ _ _	Special	. _ _ _ _ _
7	. _ _ _ _ _	2	. _ _ _ _ _
5	. _ _ _ _ _	-	. _ _ _ _ _
9	. _ _ _ _ _	6	. _ _ _ _ _
1	. _ _ _ _ _	Error	. _ _ _ _ _
4	. _ _ _ _ _	7	. _ _ _ _ _
Special	. _ _ _ _ _	0	. _ _ _ _ _
6	. _ _ _ _ _	8	. _ _ _ _ _
Divider	. _ _ _ _ _	5	. _ _ _ _ _
2	. _ _ _ _ _	+	. _ _ _ _ _
-	. _ _ _ _ _	3	. _ _ _ _ _
1	. _ _ _ _ _	Divider	. _ _ _ _ _
0	. _ _ _ _ _	-	. _ _ _ _ _
9	. _ _ _ _ _	6	. _ _ _ _ _
Error	. _ _ _ _ _	8	. _ _ _ _ _
+	. _ _ _ _ _	2	. _ _ _ _ _
7	. _ _ _ _ _	5	. _ _ _ _ _
4	. _ _ _ _ _	Special	. _ _ _ _ _
8	. _ _ _ _ _	3	. _ _ _ _ _

Figure A-2. Practice Exercises--Coding Numbers and Symbols

INSTRUCTIONS FOR FLASH CARD PRACTICE

You are familiar with the dot patterns which are used to code the various numbers and symbols used in the code matrix block. In order to increase the speed with which you can translate these dot patterns into their equivalent numbers or symbols, a set of flash cards has been given to you. One dot pattern has been printed on the face of each card. On the reverse side of the card is printed the number or symbol for which the dot pattern stands.

For each card, look at the dot pattern shown and say to yourself the number or symbol it represents. Check the accuracy of your response by turning the card over and looking at the number or symbol printed on its back. Continue in this way until you have worked through the entire deck.

Shuffle the deck and repeat the procedure described above. Continue this procedure until you have made two consecutive runs through the entire deck without making a single recognition error.

Are there any questions concerning this task? If there are no further questions, go right ahead.

WAIT HERE FOR FURTHER INSTRUCTIONS AFTER YOU COMPLETE THIS TASK.

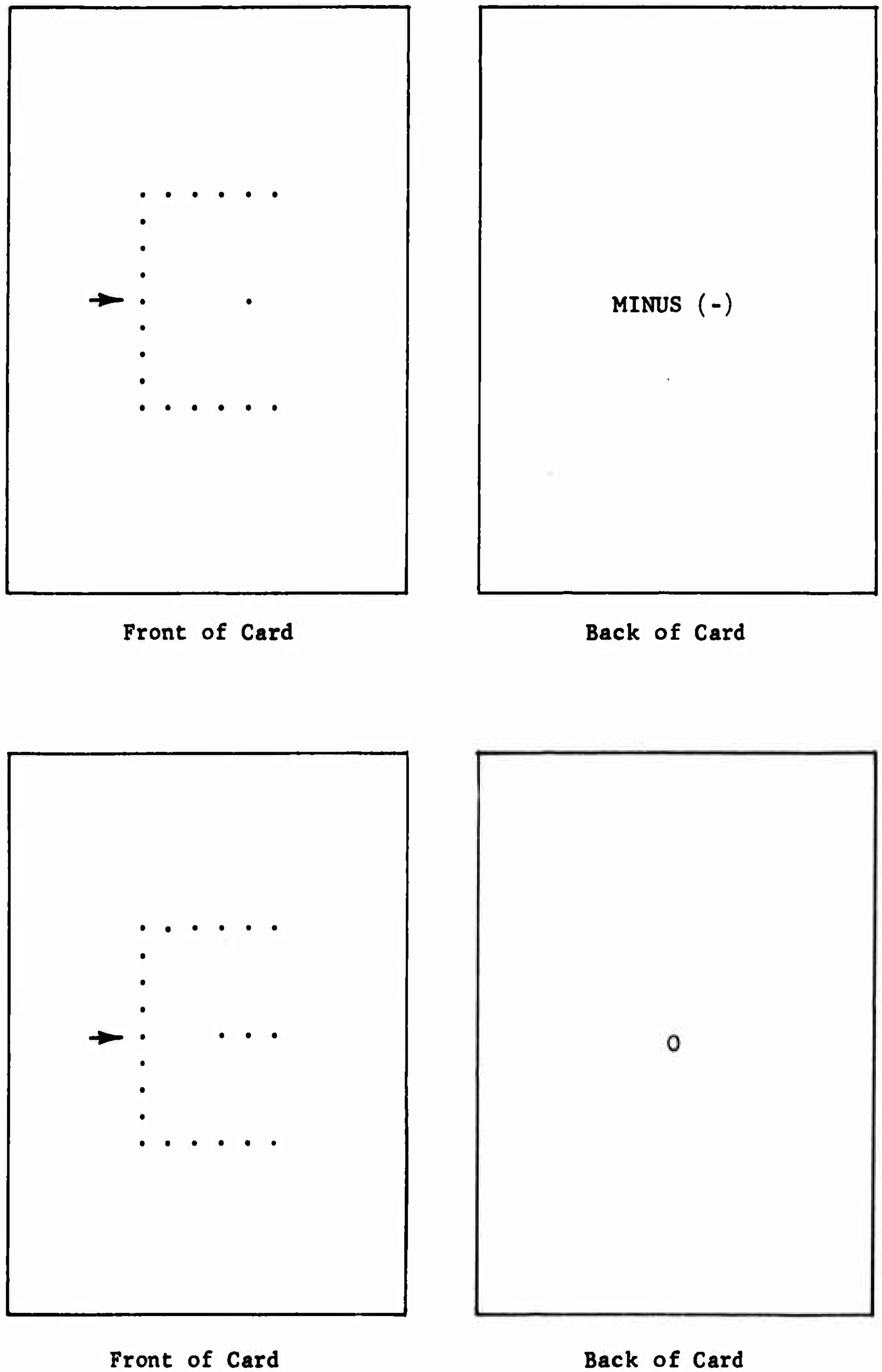

Figure A-3. Illustration of Flash Cards

NAME ______________________________ Sheet Number __________

TRIAL NUMBER

Slide Order												
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
Number Correct												

Figure A-4. Dot Pattern Recognition Record--Code Matrix Block Reading Experiment

Task Number	EXPOSURE NUMBER	RADAR ALTITUDE	LONGTITUDE	LATITUDE	TIME (GMT)	ELAPSED WORK TIME		MAGNI-FICATION
						START	FINISH	
1	104							
2			094° 42.6' W	32° 54.4' N				
3					--0946.3			
4		00570			--0952.3			
5	102			XXXXXXXXXXXX				
6			094° 41.8' W	32° 53.6'N				
7	115							
8		00540			--0937.3			
9					--1602.0			
10	112			XXXXXXXXXXXX				
11		00590			--0949.3			
12					--0931.3			
13			094° 42.3' W	32° 54.2' N				
14	114							
15	116			XXXXXXXXXXXX				

Figure A-5. Code Matrix Block Answer Sheet

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13. ABSTRACT

The general objective of the research study reported here was to determine the feasibility of having image interpreters decode sensor and terrain information encoded on imagery by direct viewing instead of resorting to use of elaborate code reading machines. The investigation sought specifically to determine: 1) speed with which image interpreters can decode designated positions of the code matrix block (CMB) data; 2) accuracy of decoding performance; 3) usefulness of CMB magnification as a means of enhancing the interpreter's speed and accuracy in decoding matrix content. Subjects in the experiment (16 graduate image interpreters of the USAINTS plus one experienced interpreter) read portions of 15 different code matrix blocks arranged in 3 sets of 5 blocks each on which reconnaissance information was encoded. The interpreters had been trained to recognize spatial patterns of dots representing the information to the point of two error-free performances. Three five-man groups decoded each matrix block, each set under one of three different levels of magnification--single power (unaided eye), two-power (stereoscope), and seven-power (tube magnifier).

In the experiment proper, achievement was measured in terms of time required for interpreters to locate the required block, decode and record the data, and number of correct decodings. Analysis of the data obtained indicated: 1) Average interpreter was 98% accurate in translation from code to clear language; 2) Direct inspection (unaided eye) was not significantly aided by magnification; 3) Use of seven-power magnification reduced decoding time over two-power magnification; 4) Practice significantly reduced decoding time; accuracy was not affected. Findings suggest utility of

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	ROLE	WT	ROLE	WT	ROLE	WT
*Image Interpretation techniques						
Image Interpretation systems						
*Image Interpreter performance						
Laboratory facilities						
Interpreter performance						
Code deciphering						
Magnification						
Matrix code block						
*Deciphering performance						
*Response accuracy						
*Deciphering rate						
Aerial reconnaissance						
Statistical analysis methodology						
Direct inspection						
Code reading machines						

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13. ABSTRACT continued

establishing training procedures and providing flash cards for interpreter practice and improvement in recognizing the spatial patterns used in encoding reconnaissance data. In addition, equipping the seven-power magnification now issued in the PI Kit with a reticle designed to aid in defining the data fields would be useful.